1.0 Study Methodology

Models Used and Analysis Assumptions

Models Used

The regional travel demand forecast models in the three metropolitan areas were used in this analysis. All three regional models employ traditional four-step modeling procedures. The use of four-step travel forecasting models is a standard practice, and this type of model has commonly been used by major metropolitan areas across the country over the last three decades to develop multi-modal travel forecasts. For all three regions, common procedures were developed to estimate the analysis metrics documented in the study. The following paragraphs describe the models used in each region in more detail.

The Four-Step Model

There are four basic phases in the traditional travel-demand forecasting process:

1. *Trip generation* forecasts the number of trips that will be made
2. *Trip distribution* determines where the trips will go;
3. *Mode choice* predicts how the trips will be served by the available modes of travel; and
4. *Trip assignment* predicts the routes that the trips will take, resulting in traffic forecasts for the highway system and ridership forecasts for the transit system.

Source: Khristy, JC, and B. Kent Lall, Transportation Engineering, Second Edition, 1998

Central Puget Sound Regional Model

The travel forecasting analyses performed in the central Puget Sound region relied on PSRC's regional model[1], which forecasts HOV, non-HOV, and transit modes. The PSRC multi-modal model was updated and validated to 1998 conditions. The model interfaces with a land use allocation model that produces population and employment forecasts for the central Puget Sound region (King, Kitsap, Pierce, and Snohomish Counties) using the STEP regional econometric model, the Disaggregated Residential Model (DRAM), and the Employment Allocation Model (EMPAL).

Vancouver Regional Model

The travel forecasting analyses performed in the Vancouver region relied on the Southwest Washington Regional Transportation Council's (RTC's) regional model. The RTC model is a variation of the Metropolitan Demand Model maintained by Metro, the Portland region's Metropolitan Planning Organization (MPO), and was updated and validated to 2000 conditions. The land use element of the model is based on household and employment forecasts by Metro for the Oregon region and by Clark County for the Vancouver region. The RTC model has a carpooling component for home-based work trips, but is not calibrated to have a high occupancy vehicle (HOV) lane component. It also includes transit modes such as express bus, local bus, and light rail.

Spokane Regional Model

The Spokane area analysis was based on the Spokane Regional Transportation Council (SRTC)'s regional travel demand model. The model is based on Growth Management Act (GMA)-consistent regional socioeconomic and demographic forecast data by traffic analysis zones, and produces output for HOV, non-HOV, and transit modes. Unlike the central Puget Sound regional model, this model does not directly produce output reflecting commercial or

[1] Land Use and Travel Demand Forecasting Model - Current Model Documentation," prepared for PSRC by Cambridge Systematics, Inc. with Urban Analytics, June 30, 2001

freight performance. For this reason, commercial vehicle trips were tabulated through a post-processing procedure. The area that encompasses the SRTC model includes all of Spokane County and the jurisdictions contained within, plus external zones that reflect travel from outlying areas into and out of the County, including Kootenai County and all of Idaho.

Model Assumptions and Limitations

All the three regional models were developed with the assumptions that people will continue to make travel decisions in 2025 as they do today and there are no significant transportation technology advances from now till then. Although all three models can perform multimodal traffic forecasts, the models do not do a very good job in forecasting people's choices of using different travel options and their reaction to value pricing (roadway tolling). For example, the existing regional models do not capture how drivers may alter their time of travel or cancel trips altogether to avoid delays or tolls. Instead, the models tend to limit the behavioral response of value pricing to the shortening of trips in order to lower travel costs and/or to a change of travel mode. The response was primarily observed as the formation of three or more person carpools due to their assumed toll-free status. For the purposes of this study, no procedures were developed to augment the model's capabilities to handle time shifting and peak spreading (i.e., travelers changing the time of travel to avoid congestion and/or the highest tolls and the related spreading of the peak periods of travel) and outright trip elimination (i.e., combining two trips into one). If trip time shifting, peak spreading and/or trip elimination were better accounted for, the results for the scenarios including value pricing might be somewhat improved.

Caution should be taken in relying on these results because of the limitations of the travel demand forecast models used in the analysis and uncertainties associated with forecasting travel behaviors far into the future in general.

Modeling Assumptions

- Modeling year: 2025;
- Time periods: 1) a two-hour PM peak period, and 2) daily;
- Fixed land use and overall level of person-trip making for each scenario;
- Tolls applied as function of roadway demand and levels of congestion; and
- Peak spreading not captured.

Other Analysis Assumptions

To ensure consistency in the analysis, the following assumptions were applied to the three urban areas:

- A 2025 baseline scenario was established as a benchmark for comparing all other scenarios. Since most analysis was done in 2004, prior to the 2005 legislative session, the transportation projects funded by the 2005 Transportation Partnership Account were not included in the 2025 baseline.
- The land use forecasts for the three regions were based on adopted land use (population and employment) projections developed by each region's Metropolitan Planning Organization (MPO) and were held constant for all analyses.
- Transportation analysis metrics were developed to evaluate how well the scenarios address traffic congestion and related topics and do not represent a full spectrum of transportation issues. The metrics were developed from travel models available for use within each region.
- Costs were developed using common planning-level cost estimating techniques that account for different unit costs from region to region.
- To help estimate the costs for each scenario, key environmental factors were assessed at the system level. Corridor level assessment was not performed because it would require corridor level design, which is beyond the scope of this study.

- Review of other potential environmental impacts focused on broad-ranging regional effects and did not include any project-level environmental studies. Environmental review focused on a few key areas and does not represent the full range of environmental issues.
- Economic analyses examined a broad range of benefits and costs associated with the scenarios. The methodology is consistent with a benefit-cost analysis conducted at a project-level, but streamlined for application at the aggregate level for the entire region.
- Value pricing strategies included in the scenarios were analyzed to the extent that they could be modeled within a region's travel forecasting process. These models do not capture the full spectrum of potential value pricing effects on travel behavior.
- This study does not attempt to define potential funding mechanisms at the local, regional, or state level needed for transportation facilities or programs analyzed.
- This study did not include project-level designs. Therefore, the study results should not be used to compare specific projects or to appropriate project funding.

Scenarios and How They Were Developed

Description of Scenarios

Various transportation scenarios were tested within each region. The intention of the scenarios developed for this study was to represent a range of possible system-wide improvements, but not to define all possibilities. The purpose was to identify which types of improvements might most effectively relieve congestion and at what cost.

The scenarios began with the development of the 2025 Baseline Scenario, a scenario that only includes projects with committed funding. From this base, the study examined three scenarios that focused exclusively on roadways, transit, or value pricing, and four mixed scenarios that included investments in more than one mode or type of capacity improvement. Additional analyses, including travel demand management and system efficiency improvements, were conducted in two of the regions.

In order to help frame the scenarios, the study team developed two capacity-unconstrained travel forecasts; these unconstrained forecasts were used to identify the highest demand corridors for both highway and transit. The Unconstrained Highway Demand Analysis assumed there was no congestion anywhere in the regions, while the Unconstrained Transit Demand Analysis assumed that everyone would have convenient access to frequent and reliable transit service. The results of the unconstrained forecasts helped to shape the combinations of highway and transit investments tested in the scenarios.

2025 Baseline Scenario

The 2025 Baseline Scenario represented existing transportation facilities, as well as future projects that are committed by the Washington State Department of Transportation (WSDOT), regional providers, and local agencies. These projects have funding secured or have a very high likelihood of being implemented by 2025. For example, this scenario included projects that are under construction or have secured funding as part of the state's Nickel Funding program, the Seattle Monorail Project (SMP) Greenline, and Sound Move Phase I. All of the following scenarios were compared to the 2025 Baseline Scenario.

Unconstrained Transit Demand

The Unconstrained Transit Demand Analysis was developed to identify demand for transit in response to a very high frequency transit system with excellent accessibility to all travelers in the region. The Unconstrained Transit Forecast assumed that transit service would be available everywhere and would provide direct, no-transfer service to every destination within the region. Under this nearly ideal transit service condition, travelers would be able to reach a transit stop via a two and a half minute walk from their homes or businesses, and would wait no more than five minutes during peak periods (seven and a half minutes during off-peak periods) for a one-seat, no-transfer ride on transit to their destination. The average travel speed for the ride on transit was assumed to be 18 mph (50 percent faster than today), except for trips that could be made at a higher average speed in the 2025 Baseline transit network. Transit fares were assumed to be consistent with today. The Unconstrained Transit Forecast results were used to identify corridors for additional transit service in the Transit Focus Scenario and the mixed scenarios, which are described below.

Transit Travel Speeds

The 18 mph average speed is a typical speed for travel on an urban rail system with station spacing that allows most travelers to access transit by walking (i.e., the Chicago Transit Authority Red Line with an average speed of 19 mph and an average station spacing of 0.6 miles and the New York City Transit “A” Line with an average speed of 18 mph and an average station spacing of 0.5 miles). As a point of reference, the average speed for transit service in Puget Sound (including local and express buses) is currently 12 mph.

Unconstrained Highway Demand

The Unconstrained Highway Demand Analysis assumed that all vehicle travelers (cars, buses, carpools, etc.) would be able to make any trip within the region at any time of day, using any combination of freeways and arterials, without experiencing any congestion. The forecast revealed the maximum demand for roadways under free-flowing conditions, and identified what highway capacity improvements would potentially be necessary to “eliminate” congestion. The Unconstrained Highway Demand Analysis results were used to identify potential corridors for additional lanes to address major congestion areas in the Highway Focus Scenario and the mixed scenarios, which are described below.

Transit Focus Scenario

The Transit Focus Scenario was built based on analysis of the Unconstrained Transit Demand Analysis and existing transit plans. It represented a very high transit system investment. This scenario consisted of transit investments that have already been identified through long-range planning or other studies, and new transit investments that address unmet transit demand, as identified through the Unconstrained Transit Demand Analysis. The transit investments included high-capacity transit (HCT) facilities such as light-rail transit (LRT) and/or monorail. This scenario also included increases in local and express bus service, commuter rail service, and passenger ferry services where applicable, to connect major population and employment centers throughout the region. This scenario was developed to evaluate how well a very heavy investment in transit alone could relieve congestion.

Pricing Focus Scenario

The Pricing Focus Scenario was analyzed for the central Puget Sound and Vancouver regions only. This scenario's underlying objective was to make more efficient use of the existing system capacity through the application of variable roadway value pricing.

The Pricing Focus Scenario assumed that the entire regional roadway network would be tolled on a per-mile basis based on the level of congestion once a threshold level of demand was met. In the Puget Sound region, carpools of three or more persons (HOV 3+) were assumed to travel toll-free under all conditions. In Vancouver, carpools faced reduced tolls but were not assumed to be toll-free. Toll rates for each roadway segment and travel direction were determined by the demand and capacity relationships of the segment at different times of day and users' willingness to pay for delay reduction, with toll rates approximating the external delay cost that each user imposes on the rest of the system. Expressed in constant 2003 dollars, tolls would vary from zero at times of low demand/no congestion, and would rise with increasing demand/delay to a ceiling of 50 cents per mile corresponding to highly congested conditions when roadway demand meets or exceeded capacity. It was assumed that meters in vehicles would locate the vehicle by roadway type and keep a running total of toll charges as the vehicle is driven.

The Traffic Choices Study

The Puget Sound Regional Council (PSRC) is currently leading the Traffic Choices Study – a demonstration project with the objective of developing a better understanding of the behavioral, policy and technical issues associated with roadway value pricing. A representative sample of drivers from throughout the region are participating in the year-long study in which five hundred vehicles from over 300 households have been outfitted with an in-vehicle, global positioning system (GPS)-based metering device. The GPS unit identifies the vehicle location and displays the monetary cost to use each roadway on a per-mile basis at the time it is approached. Participants have travel budgets established from their normal or baseline travel using the applicable toll rates before value pricing is activated. Once value pricing is turned on, participants who alter their travel behavior in such a way as to reduce their overall travel costs get to pocket the savings. The project will help researchers and policymakers better understand the value placed on road access and mobility by travelers in the central Puget Sound region.

For further information on this project, visit the project's Web site at:

http://www.psrc.org/projects/trafficchoices/

Highway Focus Scenario

The Highway Focus Scenario was based on analysis of the Unconstrained Highway Demand Analysis to construct a very high level of roadway capacity improvements. The specific capacity additions included highway projects identified in each region's long-range transportation plan with additional lanes targeted at other identified congested locations. Roadway capacity was provided both within and outside of the designated urban growth boundaries. This scenario increased capacity on major freeways and arterials in each region to meet most of the roadway demand, as determined through the Unconstrained Highway Demand Analysis. The goal in defining this scenario was to add lanes to a facility or parallel facilities to satisfy the majority of the demand identified in the Unconstrained Highway Demand Analysis. This scenario was developed to evaluate what an aggressive increase in highway capacity alone could do to relieve congestion.

Mixed Scenarios

Four combinations of the Highway, Transit, and Pricing Focus Scenarios were developed to test combinations of transit, highway, and value pricing strategies. The purpose of developing and testing these mixed scenarios was to evaluate how well multi-modal solutions would relieve congestion. These four mixed scenarios were defined as follows:

Highway and Transit Intensive: This scenario included high investments in both the transit and roadway network (about 70 to 80 percent of the lane miles of the Highway Focus Scenario and 70 to 80 percent of the service hours of the Transit Focus Scenario), to examine the interaction between large-scale capital investments in highways and transit within each region. Since both highway and transit capacity levels were lower than those assumed in the Highway and Transit

Focus Scenarios, this scenario tested how much mutual benefit could be achieved by including the most productive elements of each mode. In this scenario, the most productive highway capacity additions were retained, emphasizing highway capacity within the "core" of the regions. Less productive improvements were removed, typically on the outskirts of the region outside of designated urban growth areas (UGA). This scenario also retained transit facilities and services that exhibited the highest ridership potential within congested corridors under the Transit Focus Scenario.

Highway Emphasis: This scenario included a high investment in the roadway network (about 70 to 80 percent of the Highway Focus Scenario), but a relatively lower investment in transit improvements (more than the 2025 Baseline Scenario but much less than the Transit Focus Scenario). This scenario examined how well a primarily bus-oriented transit system, integrated with a high level of highway capacity expansion, could relieve roadway congestion. Many of the transit service enhancements used the expanded HOV[1] lane and general traffic capacity provided in this scenario's highway network. The transit system enhancements focused on service between major population and employment centers, while the highway system provided capacity expansion throughout the region.

Transit Emphasis*:* This scenario included a high investment in transit improvements (about 70 to 80 percent of the Transit Focus Scenario), but a relatively lower investment in roadway improvements (30 to 40 percent of the Highway Focus Scenario). This scenario examined the extent to which a substantial investment in HCT facilities and bus service, along with targeted highway investments within a region, could relieve congestion. Like the Highway and Transit Intensive Scenario, this scenario retained transit facilities and services that could offer the highest ridership potential within congested corridors. This scenario included highway capacity projects that focus on the regions' "cores" and minimized roadway expansion on the periphery of each region.

Transit Emphasis with Pricing: This scenario is the same as the Transit Emphasis Scenario, except for the addition of freeway variable value pricing as a function of the level of congestion. This scenario examined travel behavior changes and the potential benefits to transit and carpools with non-HOVs[2] paying tolls. The scenario also identified possible changes in people's travel routes, including shorter trips and/or diversion to arterial roads as a result of variable tolls being applied to the major freeway corridors. Existing or new HOV lanes were not tolled, nor were HOVs traveling outside of the HOV lanes tolled. The purpose of this scenario was to evaluate how well the combination of roadway value pricing, major transit investments and strategic highway capacity improvements work together to relieve congestion.

How Scenarios Were Developed

Each region developed its scenarios in a collaborative effort with the agencies participating in each region's work groups. Participants included WSDOT (Southwest Region, Eastern Region, Urban Planning Office, Urban Corridors Office, and Ferries), King County Metro, Sound Transit, Puget Sound Regional Council (PSRC), Spokane Regional Transportation Council (SRTC), Spokane Transit Authority, the Southwest Washington Regional Transportation Council (RTC), Metro (Portland's MPO), C-TRAN, Tri-Met, and the Oregon Department of Transportation.

The work groups examined the results of the Unconstrained Highway and Transit Demand Analyses to develop the Highway and Transit Focus Scenarios. For the Highway Focus Scenario, each region's work group identified the approximate number of lanes that would be

[2] For the purpose of this study, HOV is defined as vehicles with three or more persons (driver included)

required to meet the forecasted unconstrained demand. For the Transit Focus Scenario, the unconstrained transit demand forecasts were used by the Puget Sound and Vancouver groups to identify candidate corridors for HCT facilities or expanded express bus service. In Spokane, existing transit plans and policies guided the selection of HCT facilities and express bus service corridors. For the central Puget Sound and Vancouver regions, the Pricing Focus Scenario was developed in consultation with the project's expert panel members who specialize in the forecasting effects of value pricing.

Once the three focus scenarios were analyzed, each region's work group prepared two sets of highway and transit scenarios that were representative of mid-points between the 2025 Baseline and focus scenarios. The work groups discussed several versions of these scenarios before agreeing on the mixed scenarios to be tested. For the central Puget Sound and Vancouver regions, the work groups also created a new scenario that added a value pricing strategy to the Transit Emphasis Scenario. Finally, the Puget Sound and Vancouver work groups conducted additional analyses in combination with one or more of the mixed scenarios, as described below.

Additional Analyses

For the central Puget Sound and Vancouver areas, additional analyses were conducted to test enhancements to the preceding scenarios. The central Puget Sound area evaluated enhanced Transportation Demand Management (TDM) and Transportation Systems Management (TSM) strategies, an additional parallel corridor, and a high-occupancy toll (HOT) lane network. The Vancouver area evaluated enhanced TDM. Details of the additional analyses are included in Chapters 3 and 4.

Table 1-1 summarizes the scenarios studied within each region. The scenarios were tailored as appropriate for each region, as described in Chapters 2 through 4.

Table 1-1: What Was Studied in Each Region

	Puget Sound	Vancouver	Spokane
Baseline Conditions			
Existing Conditions	■	■	■
2025 Baseline	■	■	■
Unconstrained Forecasts			
Unconstrained Highway Demand	■	■	■
Unconstrained Transit Demand	■	■	■
Scenarios:			
Highway Focus	■	■	■
Transit Focus	■	■	■
Pricing Focus	■	■	
Mixed Scenario – Highway and Transit Intensive	■	■	■
Mixed Scenario – Highway Emphasis	■	■	■
Mixed Scenario – Transit Emphasis	■	■	■
Mixed Scenario – Transit Emphasis with Pricing	■	■	
Additional Analyses:			
Efficiency Improvements (TDM and/or TSM)	■	■	
I-5 Parallel Corridor	■		
High-Occupancy Toll (HOT) Lane System	■		

How Were these Scenarios Evaluated?

A variety of metrics were used to compare the performance and potential impacts of the scenarios. These metrics were broken into four categories:

- Transportation Analysis: indicated how the transportation system performed (e.g., congestion, travel time, etc.).
- Cost Estimates: identified the range of capital, operation and maintenance (O&M), right-of-way (ROW), and roadway environmental impact mitigation costs.
- Economic Analysis: assessed the monetary value of user and societal mobility benefits from relieving congestion along with the incremental costs associated with increasing and maintaining system capacity and/or implementing policies for reducing congestion.
- Environmental Review: indicated how scenarios compared regarding potential impacts to the natural and built environment (e.g., wetlands and stream impacts, and potential impacts to minority and low-income populations).

Transportation Analysis

A series of transportation analysis metrics was developed to assess the comparative performance of the scenarios in terms of their effectiveness in addressing congestion. Table 1-2 lists the analysis metrics.

Table 1-2: Transportation Analysis Metrics

Analysis Metric	Definitions
Vehicle Hours of Delay	The amount of delay (per vehicle) experienced either daily or during the two-hour PM peak period.
Commercial Vehicle Hours of Delay	The amount of delay experienced by trucks either daily or during the two-hour PM peak period.
Vehicle Delay per Mile	The intensity of delay experienced by vehicles on the state highway system measured as total daily delay per mile.
Congested Hours per Day	The number of hours per day during which a corridor is congested in the peak direction of travel.
Travel Times	The time it takes to travel, either via car or transit, during the PM peak period for a set of typical trips in the region.
Person Volumes	The number of people traveling on a facility during a day or during a two–hour peak period.
Vehicle Miles of Travel	The number of miles all vehicles travel either for an entire day or during the PM peak period.
Mode Share	The number of people traveling by transit, carpool, or alone in their cars, averaged for an entire day or for the PM peak period.
Transit Ridership Potential	The potential for high-capacity transit usage within a designated corridor.

All transportation analysis metrics were based on modeling results. The following paragraphs describe what was measured for each of the performance measures.

Vehicle Hours of Delay and Average Delay per Vehicle Trip: Vehicles are assumed to be experiencing delay when the speed is lower than the posted speed limits. Delay was calculated based on model output for two measures: average delay per vehicle trip and total vehicle hours of delay. Average delay per vehicle is a measure of the average time delay for each vehicle trip. Total vehicle hours of delay measures the delay experienced by all vehicles. Both measures of delay were calculated for daily and PM peak time periods.

Person Hours of Delay: Person hours of delay is the delay experienced by people according to two metrics: total person hours of delay in personal vehicles and average delay per person. Total person hours of delay were derived from model output and presented for both the daily period and PM peak period. Average delay per person was calculated by dividing total person hours of delay by the number of person trips, both daily and during the PM peak period.

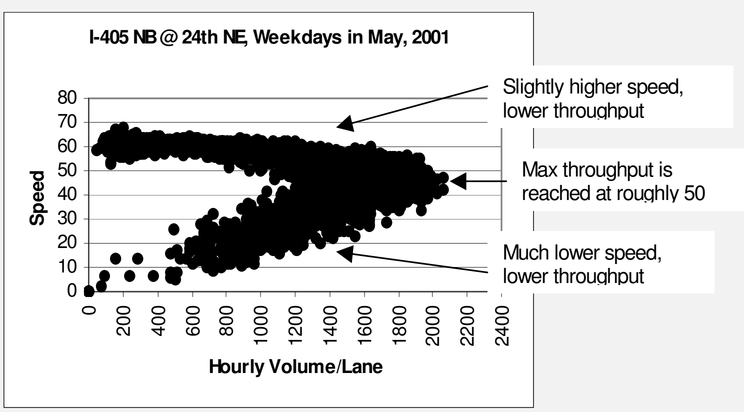
Commercial Vehicle Hours of Delay: Commercial vehicle hours of delay are a measure of the daily and PM peak period delay experienced by commercial vehicles (all trucks of two axles or more). This metric was derived from model output for Puget Sound and Vancouver. For Spokane, the metric was developed by applying existing truck percentage to model output.

Vehicle Delay per Mile: Vehicle delay per mile measures the intensity of congestion on a daily basis along freeway corridors. Total daily vehicle delay on a facility was divided by the number of centerline miles.

Congested Hours per Day: Congested hours per day are an estimate of the number of hours per day during which a roadway is congested in the peak direction of travel. For a freeway, congestion is defined as conditions where travel speeds drop below 40 to 45 mph, at which point the facility's efficiency begins to deteriorate (see call-out box below for more on efficiency). Congested hours per day were calculated using model output for each selected highway or freeway facility.

When does a highway provide its greatest capacity and efficiency for motorists?
The highest volumes of traffic on a freeway are generally not associated with the highest speeds. This is because at higher speed ranges drivers tend to adjust vehicle spacing in such a way that fewer vehicles will pass a given point of the roadway in a given period of time than at an "optimal" speed characterized by drivers' comfort with somewhat closer vehicle spacing.

The optimal speed from the standpoint of throughput efficiency can be generally examined for roadway segments as illustrated in the figure. It plots volume throughput (the higher volumes are to the right and can be read on the x-axis) against speed (the higher speeds are to the top and can be read on the y-axis), based on data collected from dozens of snapshots of performance taken during a given time period. The figure demonstrates that the highest throughput in this example– just slightly in excess of 2000 vehicles per lane per hour – was attained when highway speeds were operating between forty and fifty miles per hour.



As delay mounts, speeds drop. As conditions develop in this way, the efficiency of the highway – the number of vehicles passing the counting point in a given period of time, drops dramatically. This situation is illustrated in the lower part of the graph.

Travel Times: Travel time is a measure of the duration of a trip from the time a traveler enters a vehicle until he/she exits a vehicle at the final destination. Travel time was estimated between origins and destinations for travelers driving in cars and by transit, as estimated by the model.

For transit, the travel time also includes the initial waiting time at a transit stop plus any wait due to transfers.

Person Volumes: Person volumes are a measure of the number of people traveling on a facility in autos, commercial vehicles, or transit vehicles. Within the region, person volumes were estimated at several screenlines. Screenlines are imaginary lines drawn across parallel roadways and other transportation facilities (such as transit routes) that are used for analysis purposes.

Vehicle Miles Traveled: Vehicle miles of travel (VMT) are a metric of the total amount of vehicle travel in a region, to portray overall changes in travel activity that may occur in response to a scenario. VMT was calculated from model output by multiplying the total number of vehicle trips per day by the length of the trip (in miles).

Transit and HOV Mode Share: Mode share is the percentage of person trips made by non-HOVs, HOVs, and/or transit. It was calculated by analyzing model output for trips by mode during the PM peak periods and daily.

Transit Ridership Potential: Transit ridership potential was qualitatively estimated using the modeled forecasts of transit ridership on high capacity transit (HCT) facilities within transportation corridors.

Cost Estimation

Costs were estimated as the public costs for implementing, mitigating, operating and maintaining the infrastructure investments associated with each scenario, relative to the 2025 Baseline Scenario. Separate calculations were made for the following cost elements:

- Capital costs, including:
  - Design and construction
  - Right-of-way/property impacts
  - Roadway environmental impact mitigation
- Operations and Maintenance costs

The model estimates were adjusted according to region, whether urban or rural, and based on the type of roadway or transit facility. Project costs were published as a range of probable costs and not as a single cost number.

A risk assessment spreadsheet was also developed to determine a probable range of cost variation for each scenario. The CRA Workgroup conducted a one-day uncertainty assessment workshop to develop factors affecting overall costs in each urban area. This effort was a global assignment of variations to the regional results and not to each individual project. The team concentrated on only major

Key Cost Assumptions

Roads

- Full design standards applied;
- Widening symmetrical about centerline of the existing roadway;
- All existing interchanges in the project limits are rebuilt due to widening;
- Major connecting streets rebuilt to meet the added demand;
- Retaining walls, noise walls, drainage facilities, in line bridge widening, signals, illumination and other undetermined design features calculated as a percentage for each lane mile based on averages derived from similar projects;
- Storm water mitigation to be largely ponds in rural areas and vaults in urban areas; and
- Roadway O&M costs derived as a percent based on historical averages.

Transit

- Transit capital costs estimated for high capacity transit, bus transit and passenger ferries;
- Elements include guideway sections, transit stations, passenger ferry terminals, park-and-ride lots, maintenance bases and vehicle acquisition;
- Most high capacity transit improvements occur within existing transportation rights-of-way, usually on aerial guideways; and
- Transit O&M costs include ongoing operations and maintenance of bus, high capacity transit and ferry systems.

items of significance for variations such as increased environmental regulations, lack of resources for large programs and public insistence on enhancements. The variations were reviewed at WSDOT and adjusted according to current Cost Estimation Validation Process (CEVP) history. The cost estimates are expected to be within -5 to +25 percent of final estimates. Following consultations with several experts, ranges were used instead of single values to account for uncertainty due to the lack of project-level information.

Capital Costs: The capital costs include three major components:

- Design and construction;
- Right-of-way/property impacts; and
- Roadway environmental impact mitigation.

Each of these components is described below.

Design and construction – Design and construction cost estimates were developed using models based on unit price estimates for 'typical' roadway sections, interchanges, and transit elements for light rail transit, bus rapid transit, commuter rail, buses, and park-and-ride lots. Models of interchange, roadway, and transit elements were developed and modified with input from WSDOT and local transit agencies to reflect area case histories.

For highways, the capital costs were estimated separately for mainline facilities and interchanges. Mainline widening costs were assigned according to the type of road (limited or non-limited access highway) and area category of rural/suburban, urban, or dense urban. Interchange selection involved selecting the appropriate interchange type from a menu of 22 types for each urban area.

The highway costs were developed by segment and then tested against several known project costs in each study area to determine the reasonableness of model estimates and to ensure consistency of application. These estimates were also tested against an array of projects throughout the nation and against WSDOT cost history studies.

Transit capital costs were estimated for a variety of elements including transit guideway sections (at-grade, aerial and underground), transit stations (also at-grade, aerial and underground), passenger ferry terminals, park-and-ride lots, and maintenance bases for buses and high capacity transit vehicles. Vehicle acquisition costs were also estimated for high capacity transit vehicles, buses and passenger ferries. Transit capital costs (by corridor and system-wide) were reviewed with WSDOT, transit agency and MPO staff for reasonableness and consistency with previous estimates.

Right-of-way – Right-of-way (ROW) needs were estimated from review of aerial photos compared to the estimated needs for each improvement item. For roadways, ROW needs were estimated by reviewing existing aerial photos and comparing the visible or estimated ROW lines on the photos to the additional ROW needed, based on the suggested improvement to the facility. A property was assumed to be affected when the new ROW would approach or encroach on property structures. ROW costs were adjusted to meet future build-out conditions according to growth management boundaries.

In the central Puget Sound region, transit-related improvements would require additional right-of-way for park-and-ride facilities and transit vehicle maintenance and storage facilities. Transit right-of-way needs associated with new alignments were also identified in specific corridors where the need was apparent or previous planning was available. In most corridors, however, transit improvements were assumed to occur within existing transportation rights-of-way, usually on aerial guideways. Project-level planning for these transit lines could reveal that more right of ways may be needed.

Roadway Environmental Impact Mitigation - Estimates were developed for the mitigation costs associated with potential wetland and stream impacts. Geographic Information Systems (GIS) software was used to estimate the potential wetland and stream impacts of each scenario. Areas of impact were expressed in acres of wetlands and linear feet of stream affected.

<u>Operations and Maintenance (O&M) Costs</u>: O&M costs for the new facilities were estimated for each scenario, categorized as highway, transit or tolling-related improvements. These costs were calculated according to the square-footage of added roadway or bridge based on historical costs including the costs for periodic pavement rehabilitation, and are in addition to the $1.5 billion (2003 dollars)[3] in annual costs associated with the operation and maintenance of existing highway and transit facilities in the three regions. The highway O&M costs include an annual factor for relatively infrequent renewal costs such as pavement rehabilitation.

Transit O&M costs includes ongoing operations and maintenance of bus, high capacity transit and ferry systems, beyond the needs of the 2025 Baseline Scenario. Annual O&M costs in the forecast year were estimated using unit costs based on existing operations and assumptions consistent with other ongoing planning efforts.

Economic Analysis

Economic metrics were used to estimate the benefits and costs of the study scenarios in monetary terms, relative to the 2025 Baseline Scenario. These economic metrics are described, following a brief discussion of key assumptions/inputs to the economic benefit-cost analysis.

Benefit-cost analysis methods compare the incremental capital and ongoing O&M costs with the resulting user and societal benefits over an evaluation period that typically includes the duration of construction plus 20 to 30 years. This evaluation period allows for benefits to accrue to a reasonable level for comparison to the costs, which are largely front-loaded as driven by the long-lived capital investment portion.

Due to a number of reasons, a single future analysis year of 2025 was selected for evaluation. To accommodate the single analysis year, the capital costs were annualized by calculating the equivalent annual lease payment for each investment scenario. This annualized capital cost could then be combined with a year's worth of O&M costs for comparison to the 2025 annual benefits.

Key Economic Analysis Assumptions

- Benefits assessed for the single model analysis year (2025);
- Benefits vary +/- 20 percent from expected values;
- Costs compared to benefits include the annualized capital investment cost plus O&M costs;
- Benefits estimation relies on values of time by trip purpose and/or income segment derived from wage and salary earnings data for each region;
- One-percent per year real growth is assumed in the values of time;
- Future costs and benefits are estimated in constant 2003 dollars and are present value discounted by a real rate of 3.5 percent; and
- Revenues from pricing are assumed to be put to some beneficial use without identifying these uses and their equity distribution impacts.

[3] Sources: HPMS 2003 Data from WSDOT HQ, WSDOT Ferry, WSDOT HQ Bridge Preservation, and Parsons Brinckerhoff

All benefits and costs were estimated and expressed in 2003 dollars. Since benefits and costs were already assumed to be in constant 2003 dollars, a real discount rate of 3.5 percent was used (as opposed to a higher nominal rate which would add the expected rate of inflation to this value).[4]

Capital investment cost estimates were produced as ranges of -5% and +25% about an expected value. To similarly consider measurement error and uncertainty in assessing benefits, a +/- 20-percent range was applied to the total estimated benefits.[5] The result was that both benefit and cost estimates represent range bands rather than single point values.

Error! Not a valid bookmark self-reference. provides a flow chart of the benefit-cost analysis methodology and process. Additional details on the economic benefit-cost analysis assumptions and methodology can be found in Appendix A, *Benefit-Cost Analysis Methodology Technical Memorandum* (Parsons Brinckerhoff, November 2004).

Selecting the Future Analysis Year

Most of the study's transportation analysis metrics were well suited to having data modeled from a single, 2025 future analysis year. One exception to this was the benefit-cost analysis performance indicator. It is preferable to evaluate the benefits generated from infrastructure improvements over a 20- to 30-year evaluation period, which requires modeling at least two different analysis years, from which to interpolate and/or extrapolate benefits over the evaluation period. Ideally, a benefit-cost analysis would have model data for one analysis year corresponding to the beginning of post-construction travel benefits generation (e.g., 2025), and another analysis year at a more distant future date near the end of the evaluation period (e.g., 2050) to assess how travel benefits would change over time.

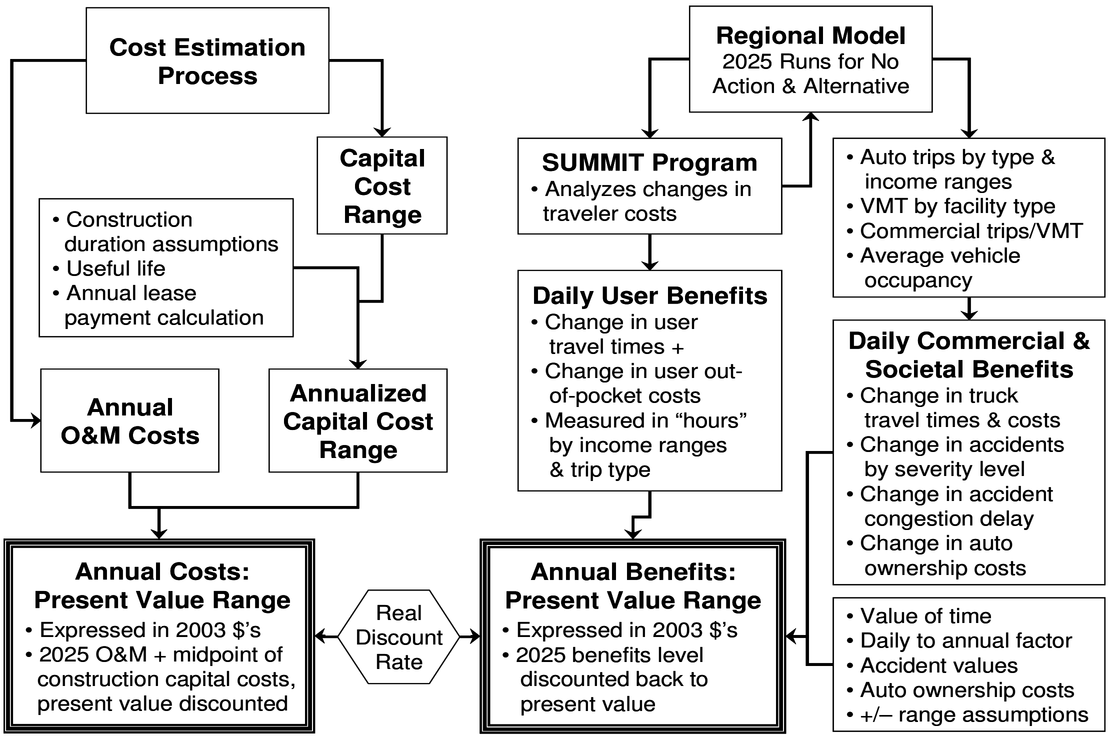
During the spring of 2004, the project team considered the advantages and disadvantages of conducting the benefit-cost analysis using one representative analysis year versus an evaluation period constructed from two analysis years. Modeling inputs such as land use forecasts were not available for any reasonable choice of a second analysis year (e.g., 2040 or 2050). As a result, a second, more future analysis year was not a viable option for this study. The only other alternative was to select an analysis year closer to the present (e.g., 2010), and either consider an artificially early evaluation period and a highly compressed construction period, or use growth rates derived from the two years to extrapolate benefits over a future period beginning with 2025.

Both of these options have distinct shortcomings, particularly since user benefits are not a simple linear function of model-predicted traffic volumes, which makes benefit estimation problematic for dates varying much from a model analysis year. Another disadvantage of two analysis years is that this would have required considerably more travel demand modeling and post processing of model data, with resulting resource and schedule implications. In the end, the project team deemed that the improvement in the benefit-cost analysis afforded by adding a sub-optimal second analysis year was minimal and not commensurate with the level of effort. As such, the single 2025 analysis year approach was chosen, and project costs were annualized for comparison to the 2025 benefits.

[4] A real discount rate measures the risk-free interest rate that the market places on the time cost of resources, when valued in constant dollars such that any inflation premiums have been extracted. For a given evaluation period, U.S. government securities of similar maturity provide an appropriate estimate of the real discount rate, where the real rate is the difference in yield between a nominal Treasury bond and a “Treasury Inflation-Indexed” bond of the same maturity. Historically, this risk-free real interest rate has generally been within the range of 3.0 to 4.0 percent, and at present, it is near the low end of this range. The U.S. Office of Management and Budget (OMB) provides guidance on an appropriate real discount rate for projects that involve federal funding. As of January 2003, the 30 year real discount rate recommendation was 3.2 percent, before any risk premium.

[5] A detailed risk assessment to assess the potential range of variation for every input parameter within the PSRC regional demand model has never been undertaken and was beyond the scope of the study. The +/– 20% range represents the majority opinion of the study’s expert review panel.

Figure 1-1: Economic Benefit-Cost Analysis Methodology Flow Chart



The mobility benefits measured as part of the overall benefit-cost analysis metric were divided into two main categories:
User benefits — defined as the combined savings in travel time and out-of-pocket costs by users of the system, including users of personal autos, transit and commercial vehicles; and
Societal benefits — defined as the indirect economic benefits of improved safety/reduced accidents and the associated avoidance of fatality, injury and property losses as well as prevented incident congestion delay, and reductions in auto ownership costs resulting from scenarios that reduce overall auto use.

The latter category of societal benefits was modeled by examining how each scenario changed VMT relative to the 2025 Baseline. In the case of auto ownership, overall changes in annual VMT affect owner depreciation costs, and on the margin, for a small number of households, may impact how many vehicles the household owns. The same changes in VMT, as well as the redistribution of VMT between arterials (higher accident rates) and freeways (lower accident rates), affect the number and severity of traffic accidents. A scenario may result in either net societal benefits or disbenefits, depending on how VMT changes and redistributes relative to the 2025 Baseline.

The following economic metrics were prepared for each investment or value pricing scenario relative to the 2025 Baseline Scenario:

- Benefit and cost present value ranges — the discounted present value of the 2025 annual benefit range and the discounted present value of the annualized cost range (including capital and O&M costs);
- User benefits per person trip by mode/trip type — user benefits as distributed by auto, transit and commercial trip modes on a per-trip basis, with user benefits defined as the

net improvement in travel times and out-of-pocket user costs (excluding safety-related and auto ownership benefits which are viewed as more indirect societal benefits);

- User benefits per trip by personal and commercial travel (range midpoint values) — similar to the above, but aggregating auto and transit into personal travel. Range midpoints are the expected or calculated values to which +/- 20 percent ranges were applied;
- Annual person-hours of delay savings per $1 million total capital investment — this measure annualizes the model predicted daily hours of delay saved by the each scenario's total capital investment cost in millions (in today's dollars *before* present value discounting);

Environmental Review

Several environmental metrics were estimated to indicate each scenario's potential impacts, particularly as they relate to costs associated with potential roadway environmental impact mitigation. They are not intended to cover a full range of environmental issues, but provide a starting point for assessing each scenario. The results are based on conceptual alignments and are therefore not suitable for the analysis of impacts at the corridor or project level.

Key Environmental Review Assumptions

- Used estimated lane/shoulder/drainage widths for highway expansions;
- High-Capacity Transit improvements are mostly on aerial guideways within existing ROW;
- GIS layers used to represent location and extent of wetlands/streams;
- Transit maintenance facilities and P&R lots impact wetlands/streams at same ratios as highway expansions;
- Noise impacts occur when vehicles/hour increase 1000+ over 2025 Baseline;
- Air quality analysis assumes current emission regulations for automobiles; and
- Minority and low-income populations identified using Puget Sound averages.

Air Quality: Using model output and regional input files to the Mobile 6.2 emissions model, emissions for carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x) were calculated to estimate the daily pollutant emissions for each scenario. Additionally, greenhouse gas emissions were estimated from the estimated regional fuel consumption for each scenario.

Noise: Model output was used to evaluate roadway segments, to determine whether segments with substantial traffic volumes (over 1,000 vehicles per hour) would increase in volume sufficiently to show a noticeable increase (three decibels [dBA] or greater) in noise levels. Noise impacts from rail improvements were discussed qualitatively.

Minority and Low-Income Populations: This study identified potential impacts to minority and low-income populations at a region-wide level and did not discuss impacts to particular communities. The analysis defined minority and low-income populations according to U.S. Census criteria and generally identified their locations by comparing Census data with regionally defined thresholds. The study then discussed the potential range of impacts that could be associated with each scenario.

Land Use: The objective of this impact measure was to identify potential land use issues that might be associated with the various scenarios. The discussion includes a qualitative evaluation of each scenario's consistency with the GMA and other land use plans and policies in the study area. The scenarios were compared to plan objectives and each scenario's ability to meet these objectives. Results of the land use analysis consisted of a qualitative evaluation of each scenario's overall consistency with urban growth and land use policies.